

Part I

DYNAMICS OF FLEXIBLE MULTI-BODY
MECHANISMS AND MANIPULATORS

An Overview

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INTRODUCTION

- A. FLEXIBILITY CAN BE A MAJOR LIMITATION TO THE PERFORMANCE OF HIGH PERFORMANCE CONVENTIONAL MACHINE SYSTEMS.
 - 1. NOISE
 - 2. VIBRATION
 - 3. WEAR
 - 4. PREMATURE FAILURES
 - 5. DESTABILIZE CONTROL
- B. THE CURRENT STATE-OF-THE-ART OF ROBOTIC MANIPULATORS IS LIMITED BY THE EFFECTS OF SYSTEM FLEXIBILITY.

THE STATE-OF-THE-ART OF THE
ROBOT DYNAMICS AND CONTROL[†]

- *NOW:
(CURRENT COMMERCIAL SYSTEMS)
- *IN 5 YEARS
(LABORATORY DEMONSTRATED)
- *IN 10 YEARS
(CURRENT RESEARCH ISSUES)

[†]This chart defines the time frames for the review of the state of the art for robotic systems which follow and provide the basis for the future projections

NOW

- 1. ROBOTS ARE:**
 - * Not Robots
 - * Individual Arms on Fixed Bases, or
 - * Simple Guided Vehicles
- 2. MECHANICAL DESIGN :**
 - * Heavy, Rigid and Slow
- 3. SENSORS :**
 - * Simple Joint Transducers
 - * Primitive 2-D Vision
 - * Rudimentary Force Sensors
- 4. ACTUATORS :**
 - * Heavy and Low Power
 - * Troublesome Transmissions
- 5. END EFFECTORS :**
 - * Binary
 - * With Simple Sensors
 - * Special Purpose Tools
- 6. MOTIONS :**
 - * Not Dynamic - "Quasi-Static"
 - * Speeds Below Structural Resonances
- 7. CONTROL :**
 - * Primitive Linear Joint Control
 - * Low Performance
 - * No Absolute Position Accuracy
 - * Only Static Force Control
 - * No Dynamic Trajectory Planning

IN 5 YEARS

1. ROBOTS ARE:

- * Still Not Robots
- * 2 or 3 Fixed Arms Working Together
- * Some Mobility

2. MECHANICAL DESIGNS :

- * Rigid, Light and Faster

3. SENSORS :

- * Still Mostly Joint Transducers
- * Some VLSI 2-D Vision
- * Simple End-Point Sensors

4. ACTUATORS :

- * Lighter Weight and Improved
- * Direct Drives

5. END EFFECTORS :

- * Some Controlled Mobility
- * Position, Force and Limited Tactile Sensing
- * Commercial Tools for Some Tasks

6. MOTIONS :

- * Control Permits "Dynamic" Performance
- * Speeds Below Structural Resonances

7. CONTROL :

- * Combined Position and Force
- * "Work-Space" Rather Than of the Joints
- * Insensitive to Environmental Changes
- * Optimal Dynamic Trajectory Planning

IN 10 YEARS

1. ROBOTS MAYBE :

- * Robots
- * Coordinated Multiple and Mobile Arms
- * Self-Contained with Walking Ability

2. MECHANICAL DESIGNS :

- * Very Light, flexible and fast

3. SENSORS :

- * New Sensor Technologies for Control
- * High Speed 3-D Vision
- * High Resolution Tactile Sensors

4. ACTUATORS :

- * High Performance
- * New Technologies - Muscle Types

5. END EFFECTORS :

- * Sensitive and Dexterous Hands
- * Intelligent Motion and Sensing
- * Intelligent Tools for Specific Tasks

6. MOTIONS :

- * Dynamically Tuned
- * Flexibility Exploited for Performance

7. CONTROL :

- * Issues of Control and Performance in Most Cases Will Move to a Higher Level.
- * Questions of Control of Individual Robot Actions Will be Transparent.